CSE331: Microprocessor Interfacing and Embedded Systems

Lecture#17: General Purpose Timer (Chapter#15)

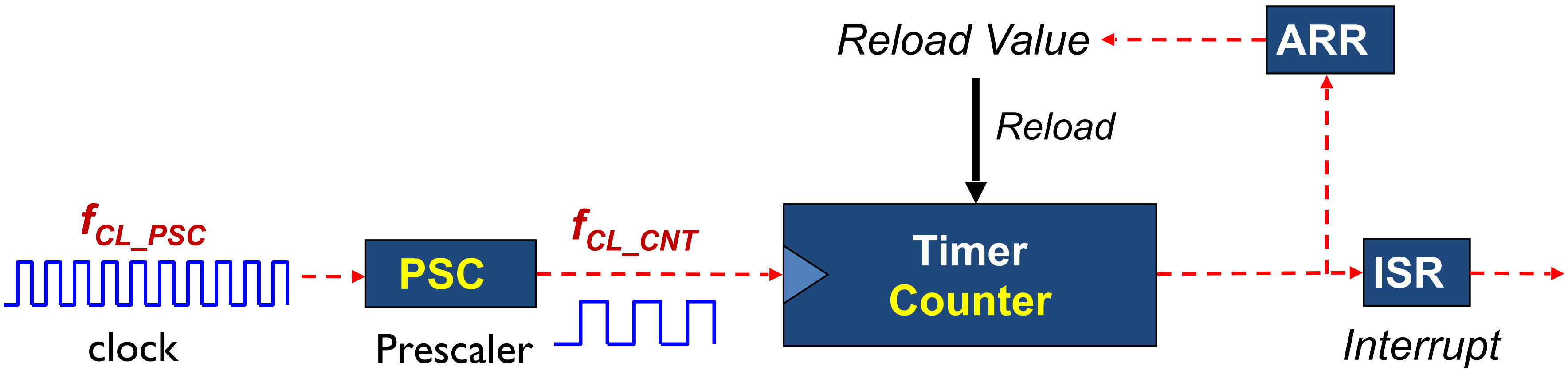
Spring, 2025

Courtesy: Mohammad A. Qayum, Ph.D.
ECE, NSU, Dhaka, Bangladesh

Timer

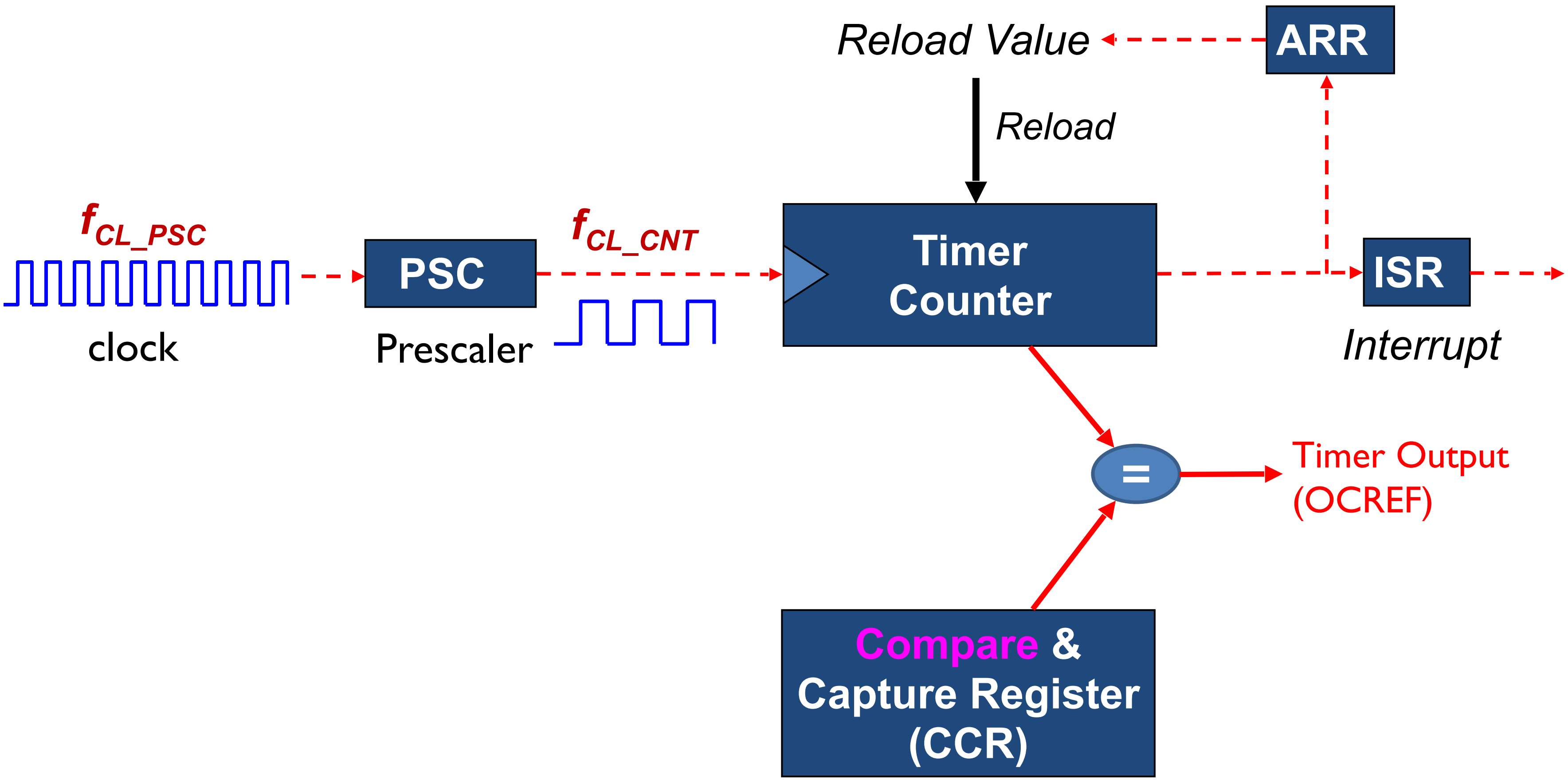
- Free-run counter (independent of processor)
- Functions
  - Input capture
  - Output compare
  - Pulse-width modulation (PWM) generation
  - One-pulse mode output

Timer: Clock

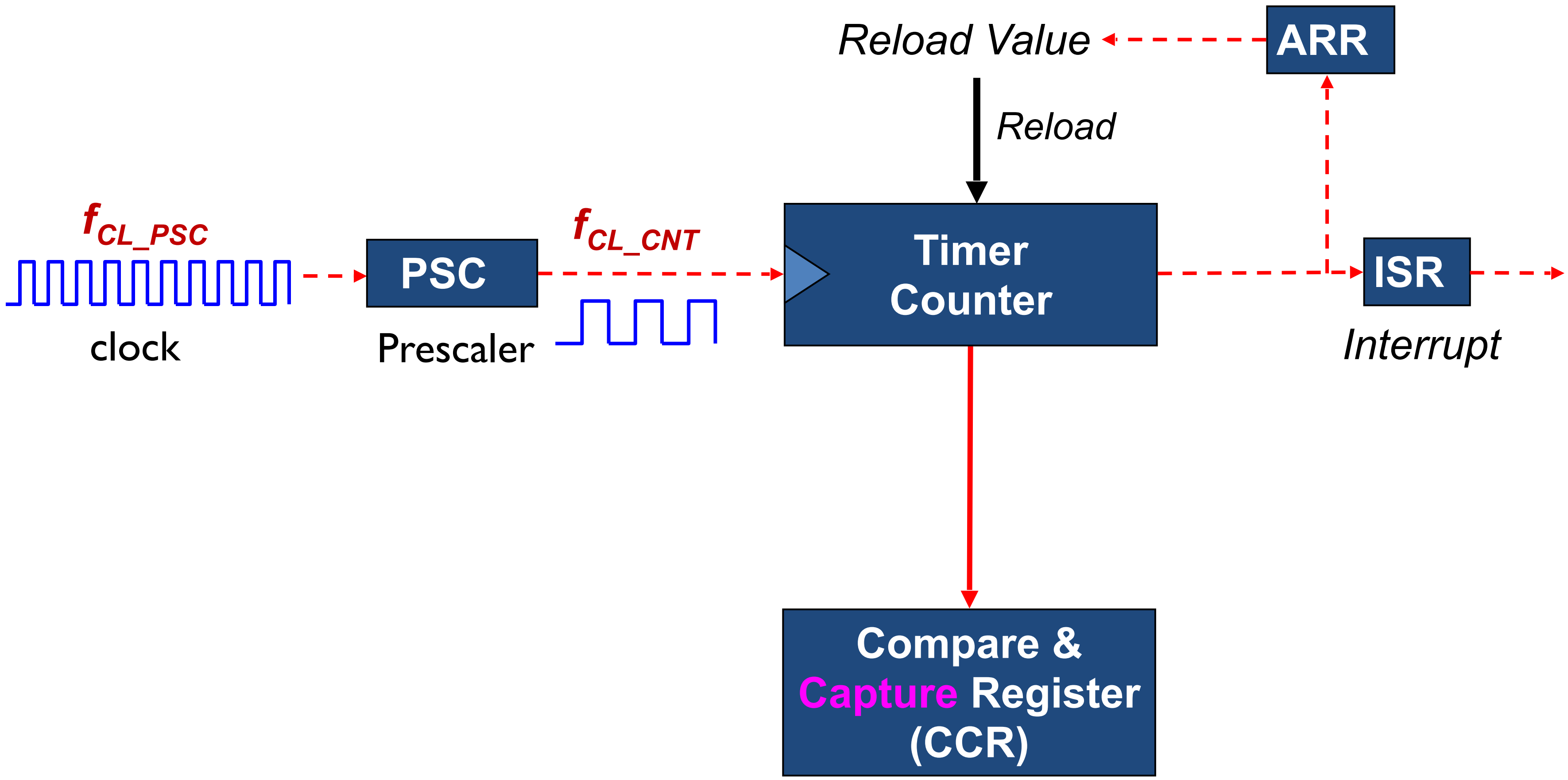


$$f_{CK\_CNT} = \frac{f_{CL\_PSC}}{PSC + 1}$$

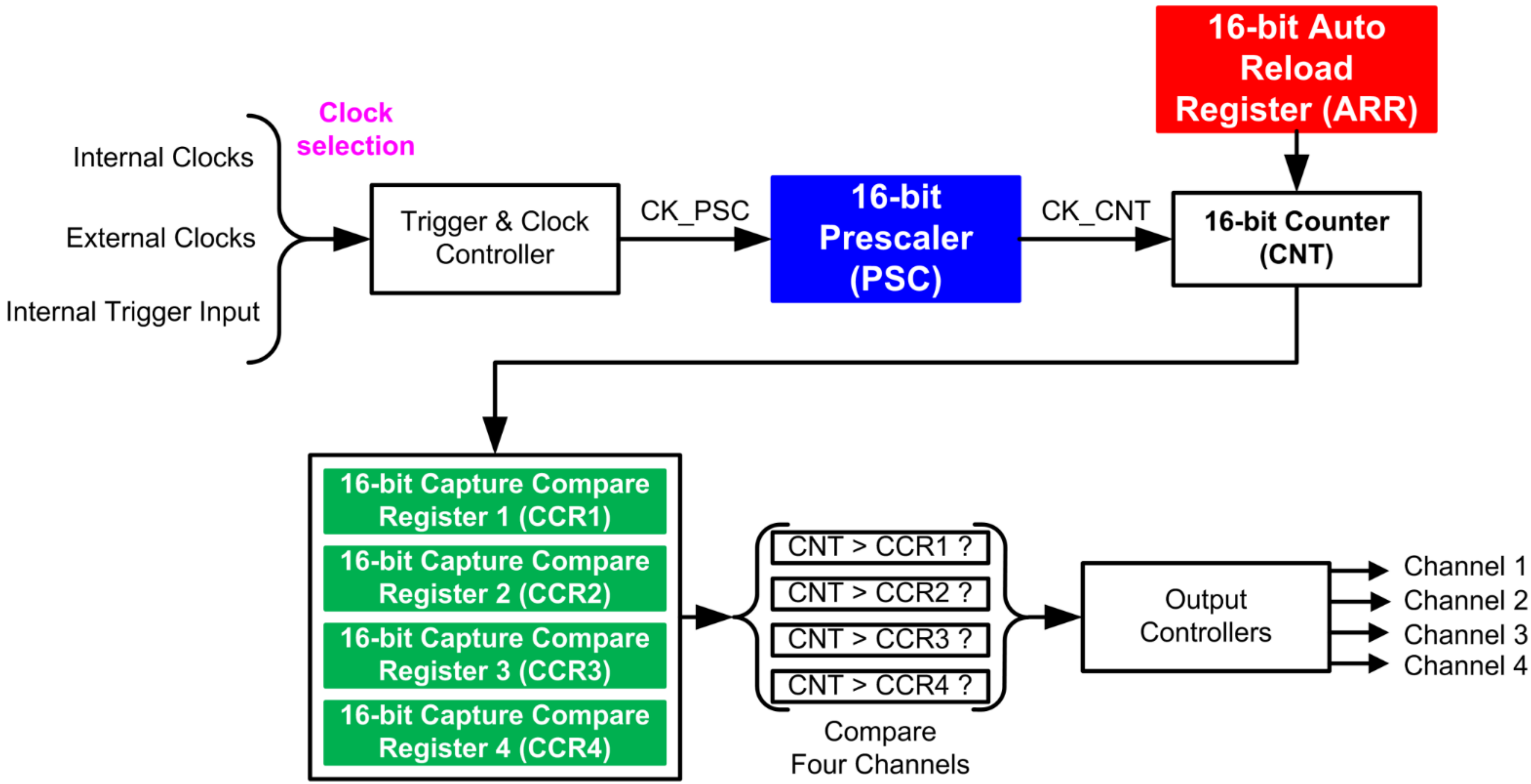
Timer: Output



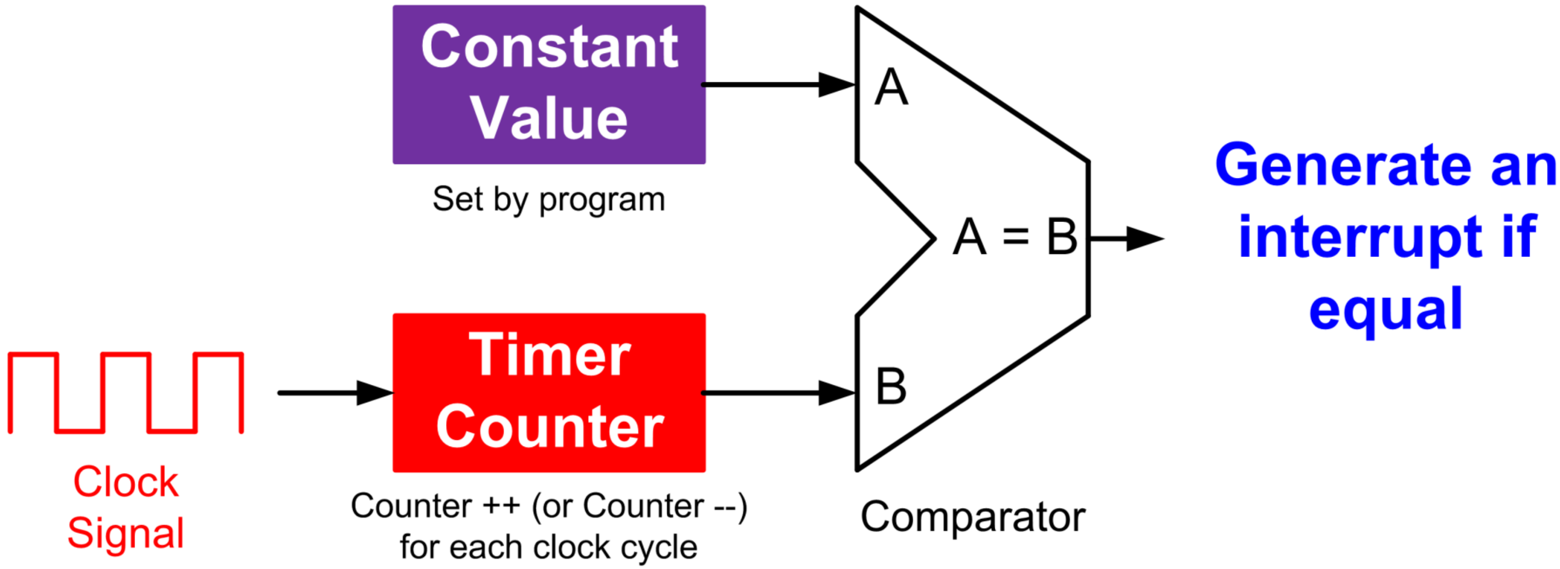
Timer: Input Capture



Multi-Channel Outputs

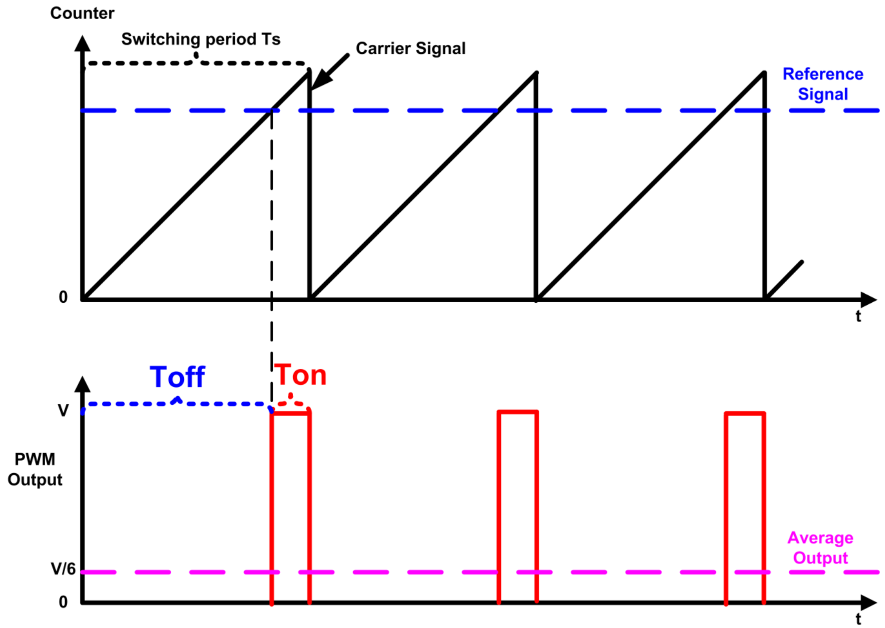


Output Compare



Output Compare Mode (OCM)	Timer Output (OCREF)
000	Frozen
001	High if CNT == CCR
010	Low if CNT == CCR
011	Toggle if CNT == CCR
100	Forced low (always low)
101	Forced high (always high)

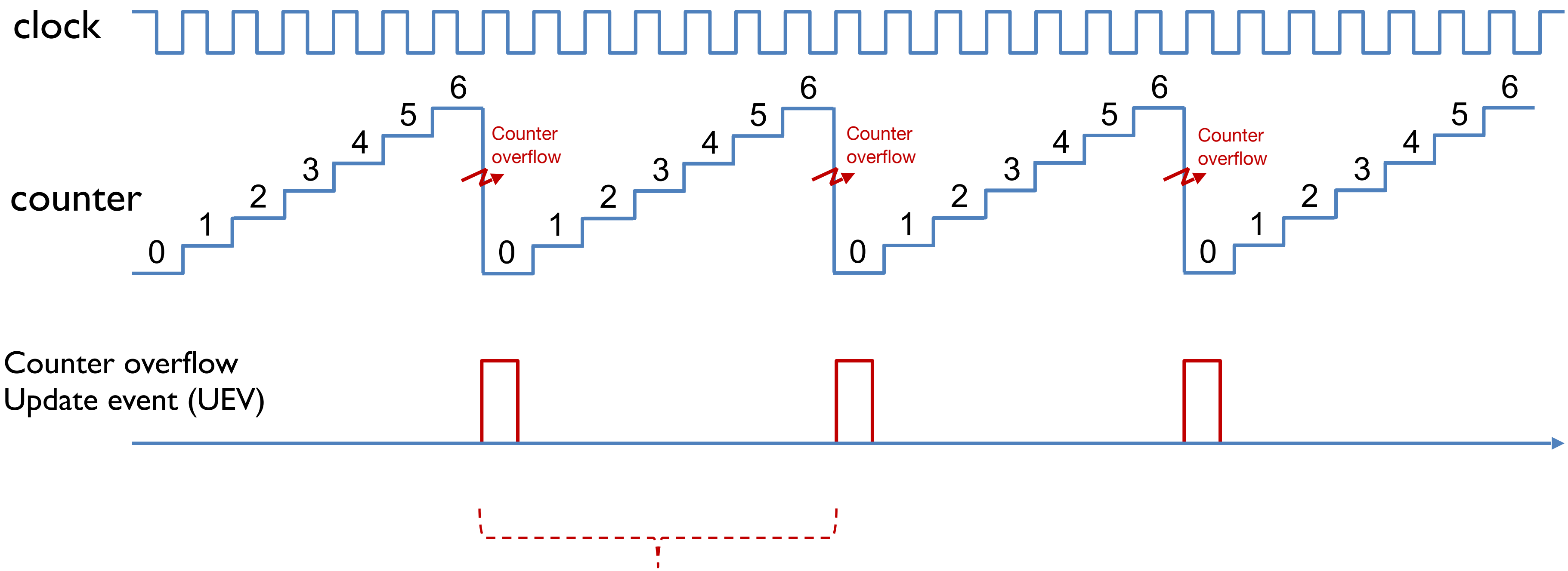
PWM Mode



Mode	Counter < Reference	Counter ≥ Reference
PWM mode 1 (Low True)	Active	Inactive
PWM mode 2 (High True)	Inactive	Active

Edge-aligned Mode (Up-counting)

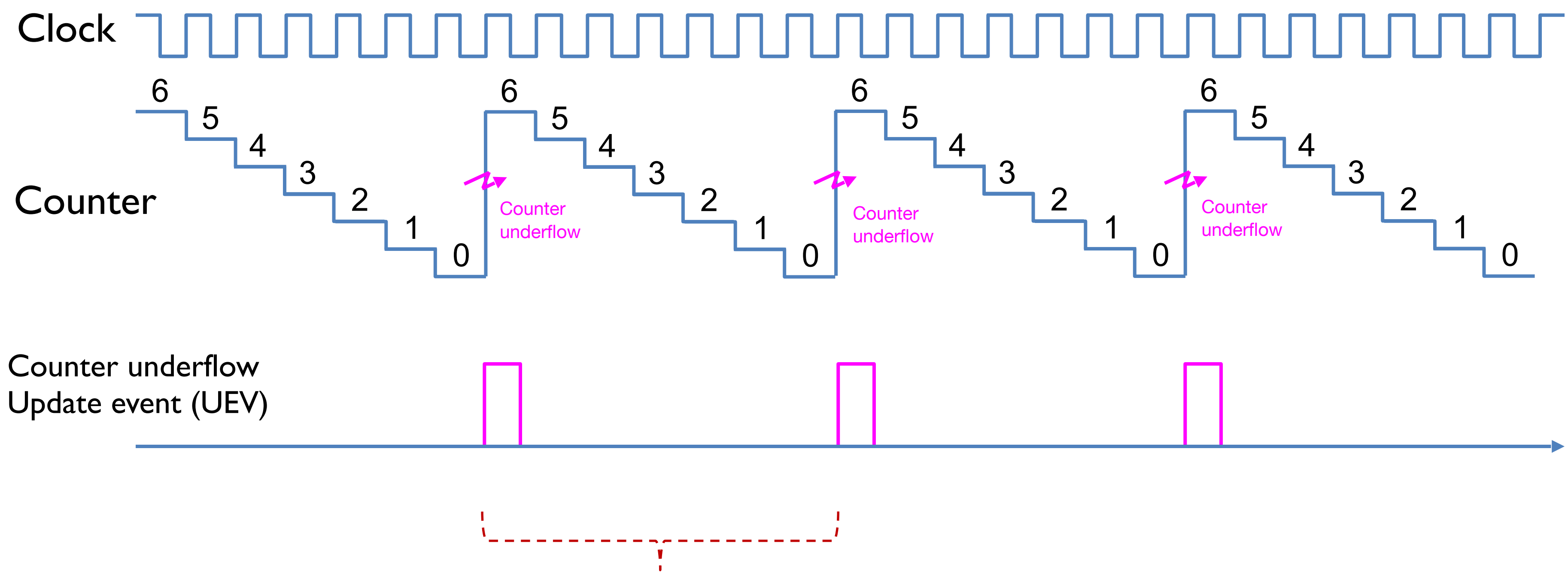
ARR = 6, RCR = 0




```
Period = (1 + ARR) * Clock Period
       = 7 * Clock Period
```

Edge-aligned Mode (down-counting)

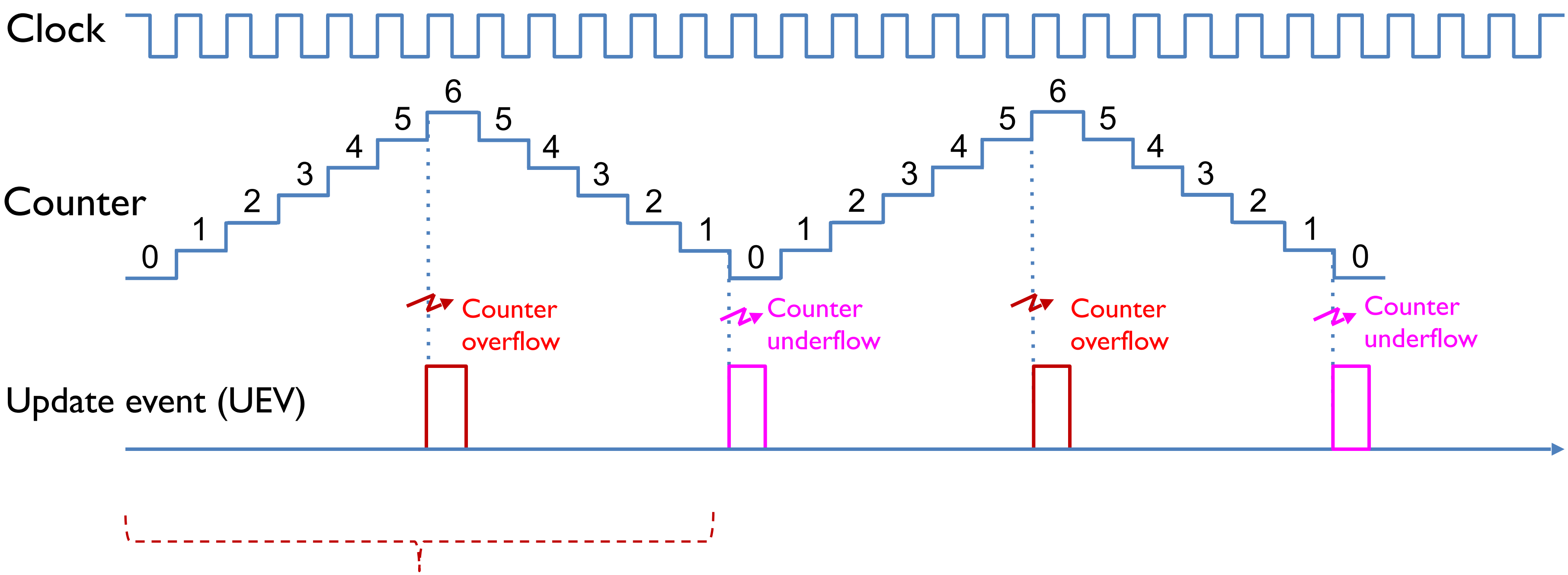
ARR = 6, RCR = 0




```
Period = (1 + ARR) * Clock
Period
         = 7 * Clock Period
```

Center-aligned Mode

ARR = 6, RCR = 0



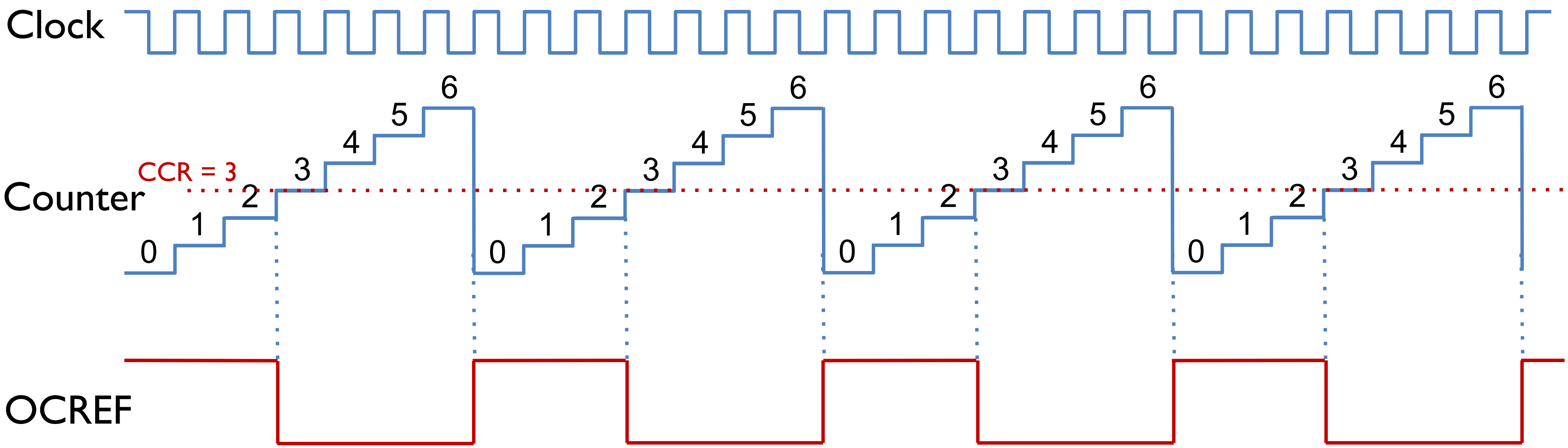

```
Period = 2 * ARR * Clock
Period
       = 12 * Clock Period
```

PWM Mode 1 (Low-True)

Mode 1

Timer Output = $\begin{cases} \text{High if counter} < \text{CCR} \\ \text{Low if counter} \geq \text{CCR} \end{cases}$

Upcounting mode, ARR = 6, CCR = 3, RCR = 0



$$\text{Duty Cycle} = \frac{\text{CCR}}{\text{ARR} + 1} = \frac{3}{7}$$

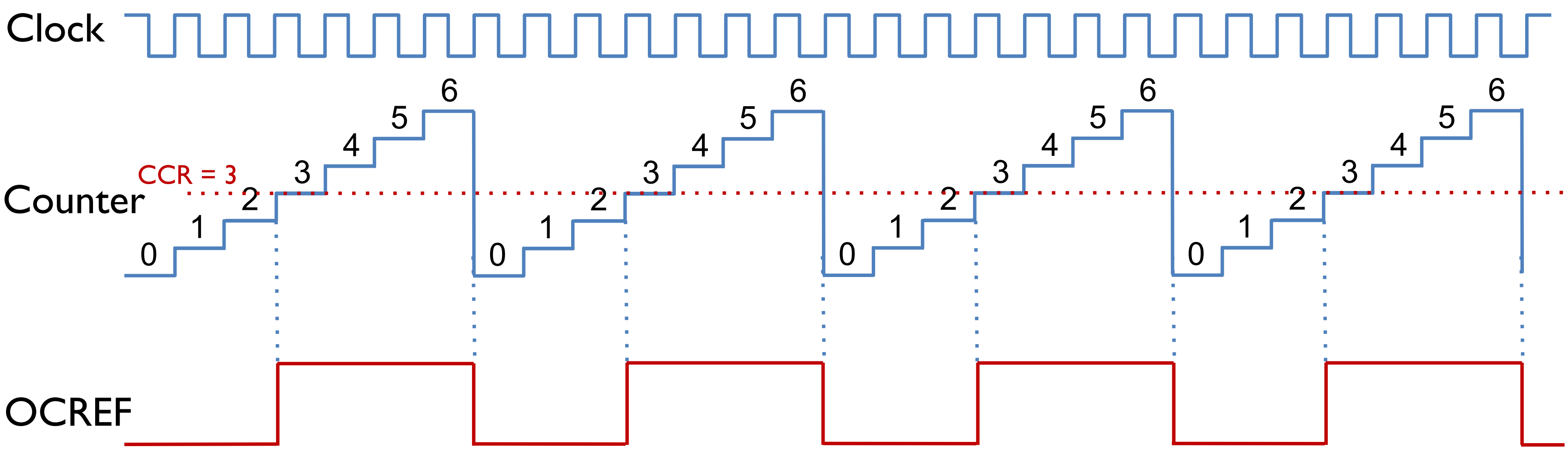
Period = (1 + ARR) * Clock Period
= 7 * Clock Period

PWM Mode 2 (High-True)

Mode 2

Timer Output = { Low if counter < CCR ; High if counter ≥ CCR

Upcounting mode, ARR = 6, CCR = 3, RCR = 0




```
Duty Cycle = 1 - CCR / (ARR + 1)
           = 4 / 7
```

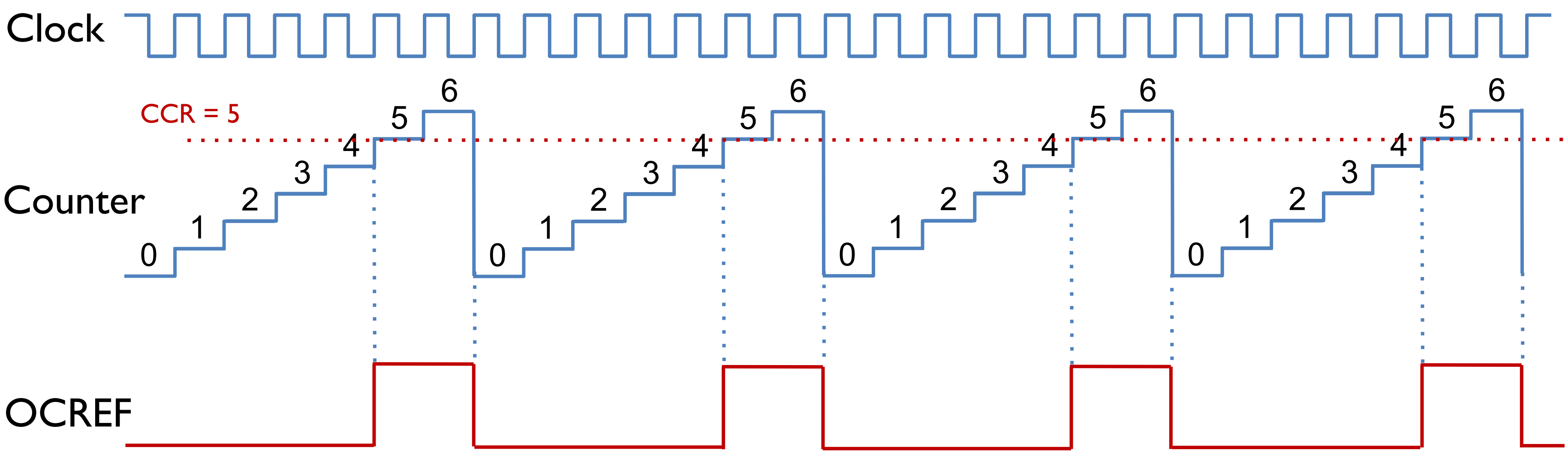
```
Period = (1 + ARR) * Clock Period
       = 7 * Clock Period
```

PWM Mode 2 (High-True)

Mode 2

Timer Output = $\begin{cases} \text{Low if counter} < \text{CCR} \\ \text{High if counter} \geq \text{CCR} \end{cases}$

Upcounting mode, ARR = 6, CCR = 5, RCR = 0



$$\text{Duty Cycle} = 1 - \frac{\text{CCR}}{\text{ARR} + 1} = \frac{2}{7}$$

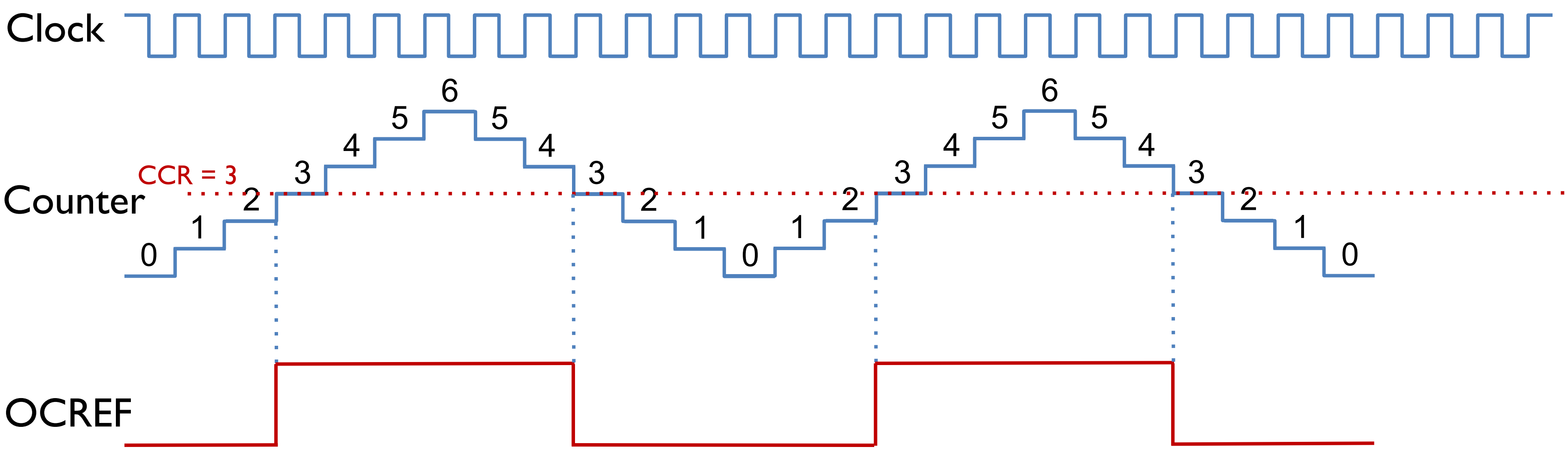
$$\text{Period} = (1 + \text{ARR}) * \text{Clock Period} = 7 * \text{Clock Period}$$

PWM Mode 2 (High-True)

Mode 2

$$\text{Timer Output} = \begin{cases} \text{Low if counter} < \text{CCR} \\ \text{High if counter} \geq \text{CCR} \end{cases}$$

Center-aligned mode, ARR = 6, CCR = 3, RCR = 0



$$\text{Duty Cycle} = 1 - \frac{\text{CCR}}{\text{ARR}} = \frac{1}{2}$$

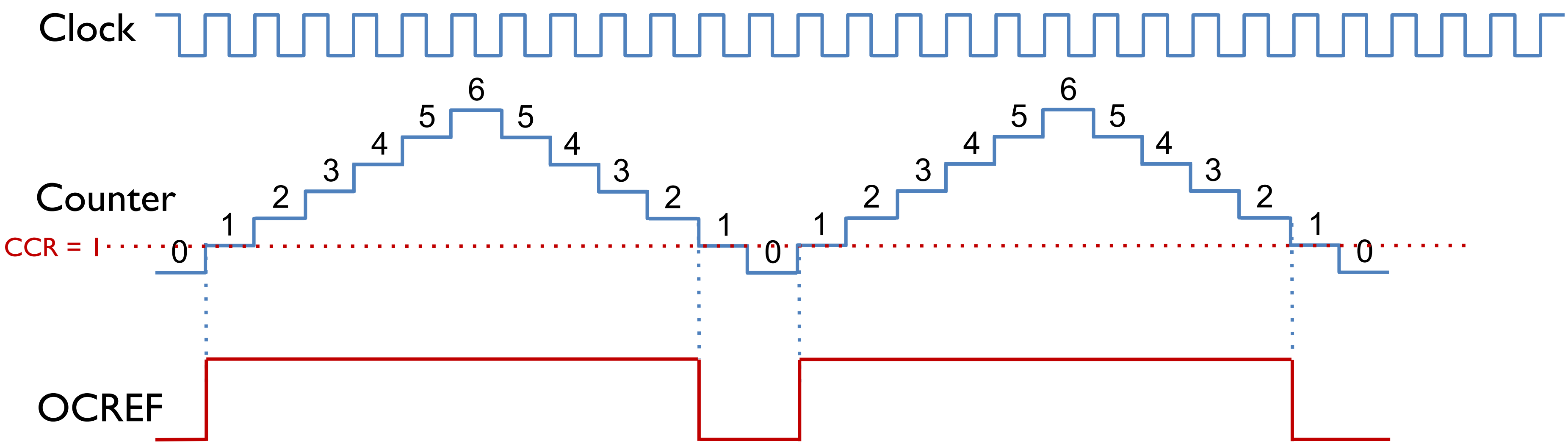
$$\text{Period} = 2 * \text{ARR} * \text{Clock Period} = 12 * \text{Clock Period}$$

PWM Mode 2 (High-True)

Mode 2

$$\text{Timer Output} = \begin{cases} \text{Low if counter} < \text{CCR} \\ \text{High if counter} \geq \text{CCR} \end{cases}$$

Center-aligned mode, ARR = 6, CCR = 1, RCR = 0

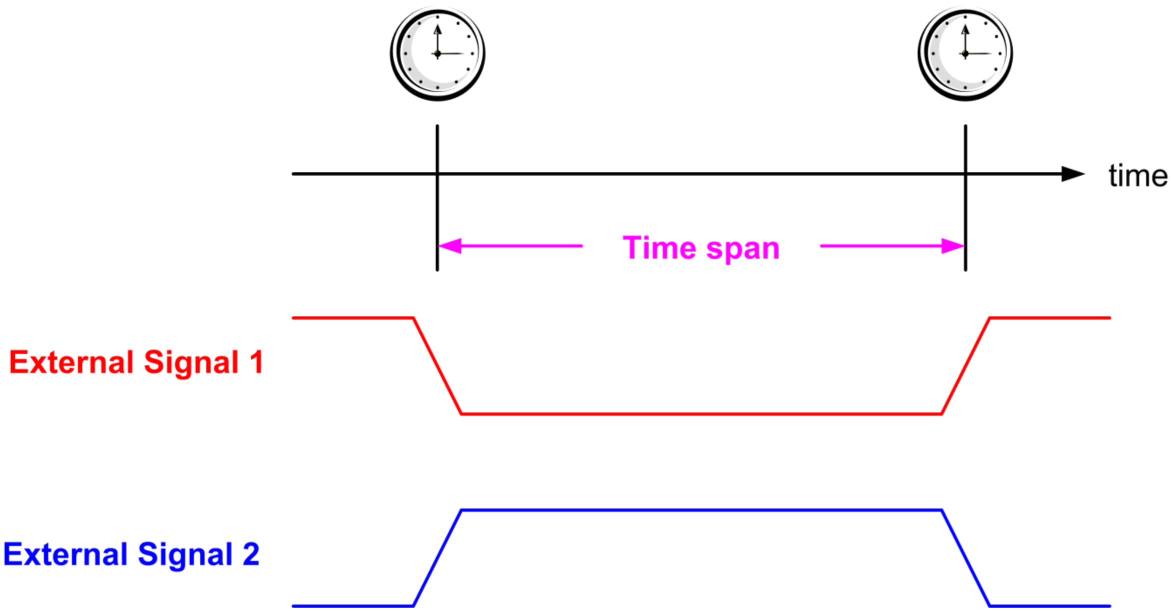


$$\text{Duty Cycle} = 1 - \frac{\text{CCR}}{\text{ARR}} = \frac{5}{6}$$

$$\text{Period} = 2 * \text{ARR} * \text{Clock Period} = 12 * \text{Clock Period}$$

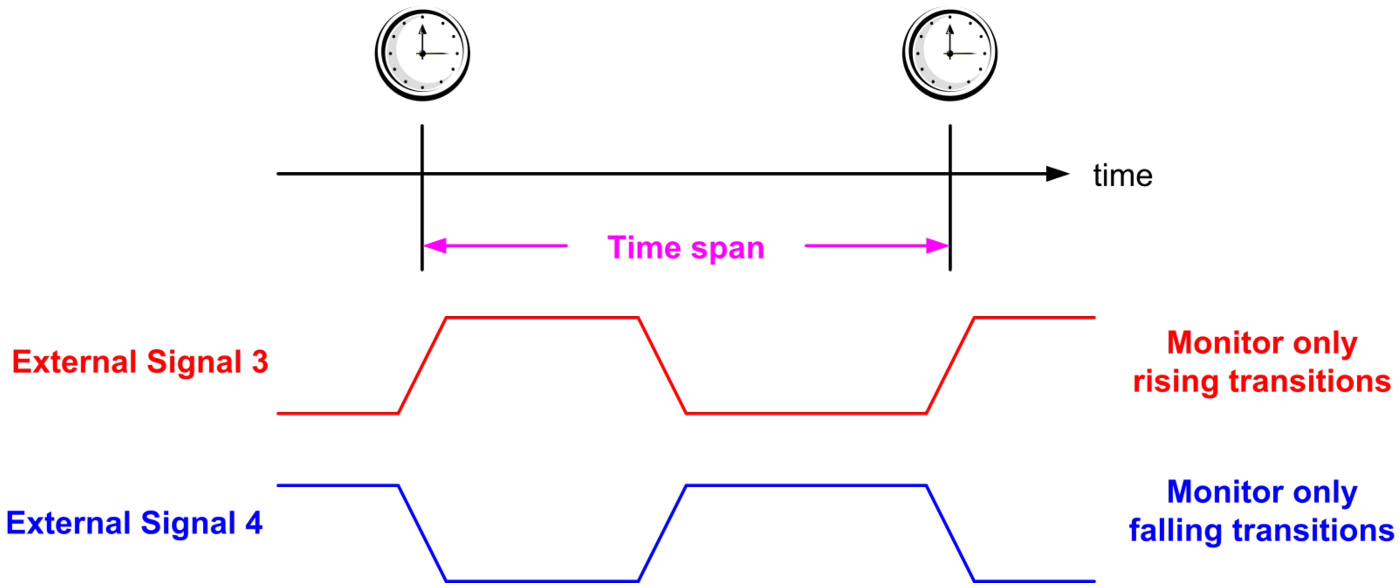
Input Capture

- Monitor both rising and falling edge

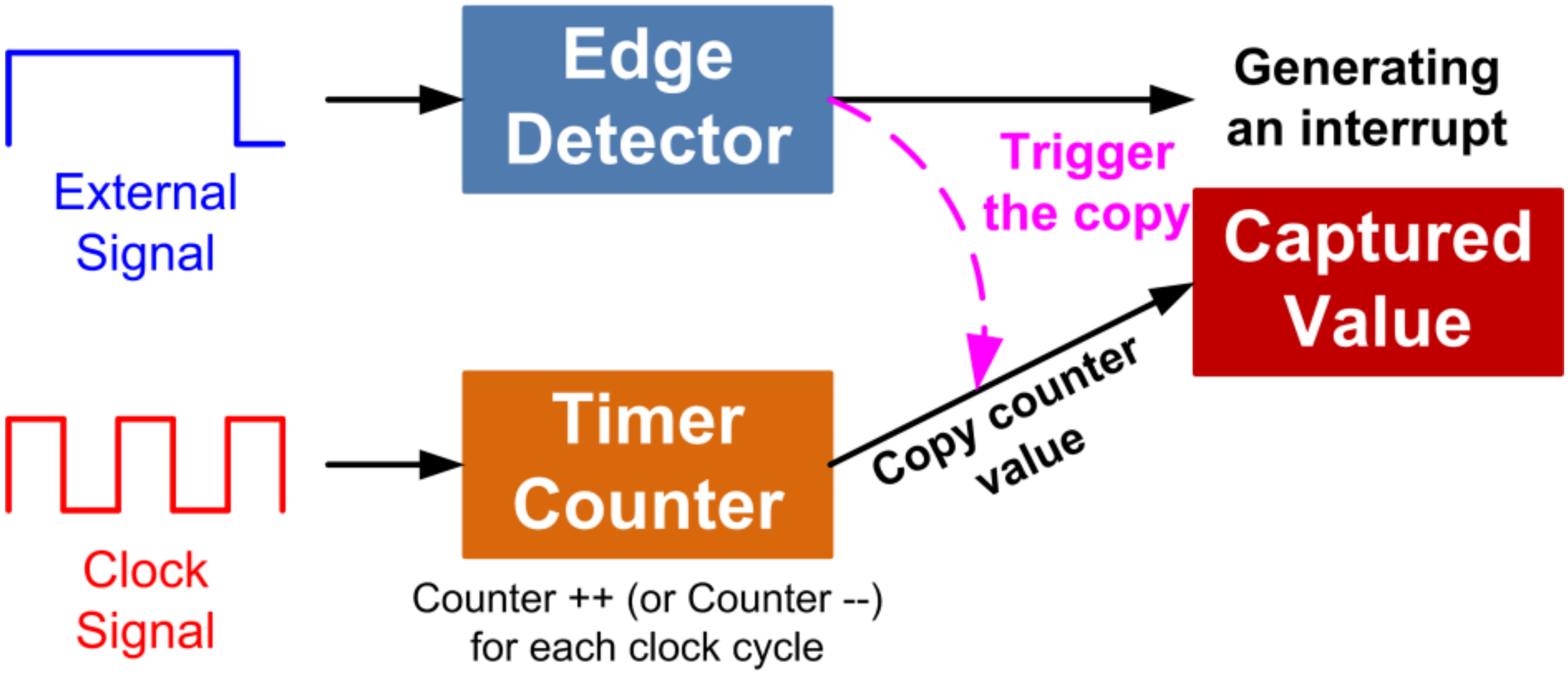


Input Capture

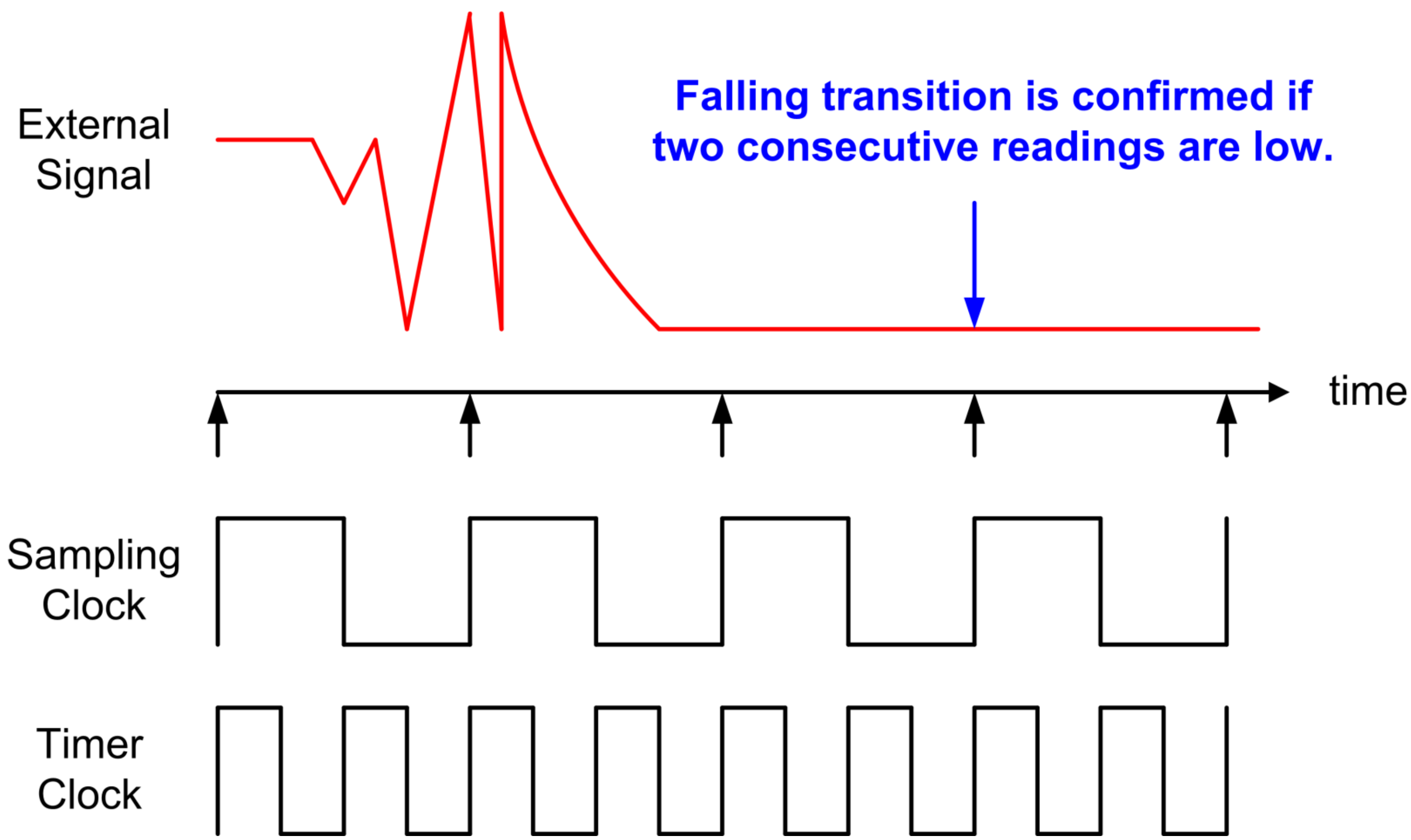
- Monitor only rising edges or only falling edge



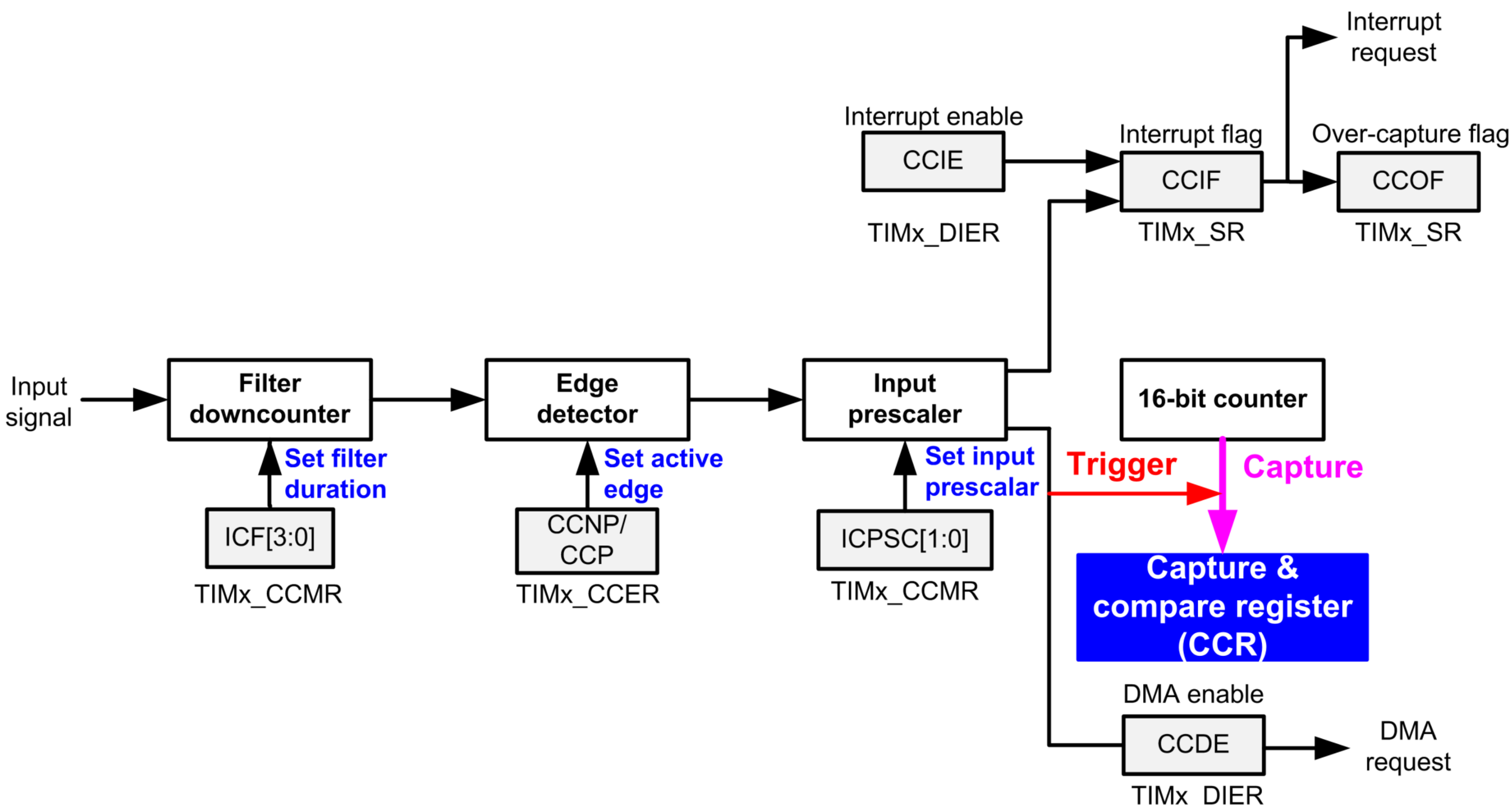
Input Capture



Input Filtering



Input Capture Diagram



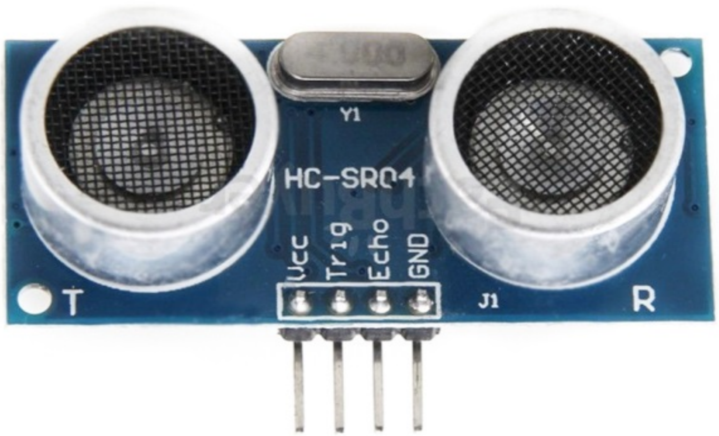
Ultrasonic Distance Sensor

$$Distance = \frac{Round\ Trip\ Time \times Speed\ of\ Sound}{2}$$

$$= \frac{Round\ Trip\ Time(\mu s) \times 10^{-6} \times 340m/s}{2}$$

$$= \frac{Round\ Trip\ Time(\mu s)}{58}$$

Ultrasonic Distance Sensor

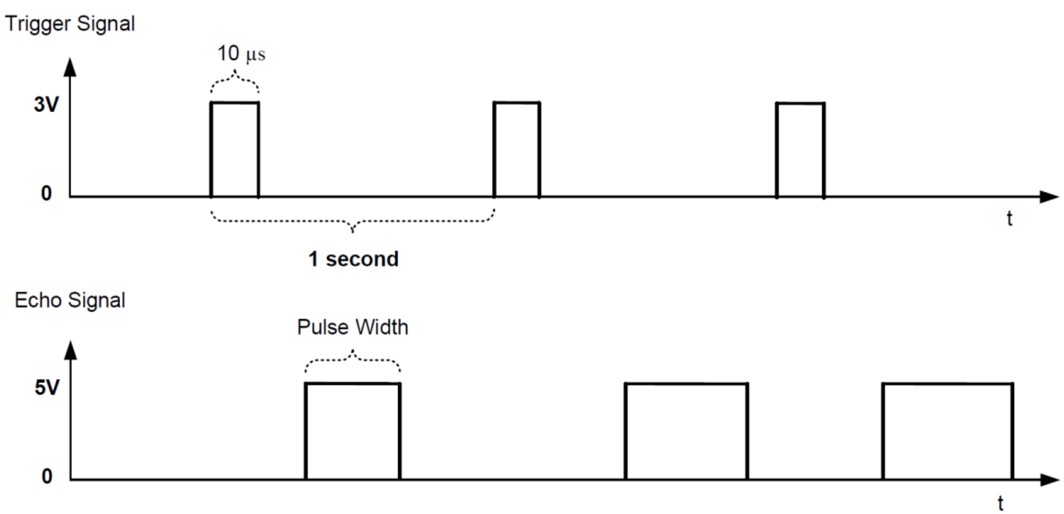


The echo pulse width corresponds to round-trip time.

$$Distance\ (cm) = \frac{Pulse\ Width\ (\mu s)}{58}$$

or

$$Distance\ (inch) = \frac{Pulse\ Width\ (\mu s)}{148}$$



If pulse width is 38*ms*,
no obstacle is detected.

The sensor can measure a distance between 2 *cm* and 400 *cm*, with a resolution of 0.3 *cm*, and the corresponding echo pulse width is between 150 μs and 25 *ms*. When the sensor detects no object, the echo pulse width is 38 *ms*.

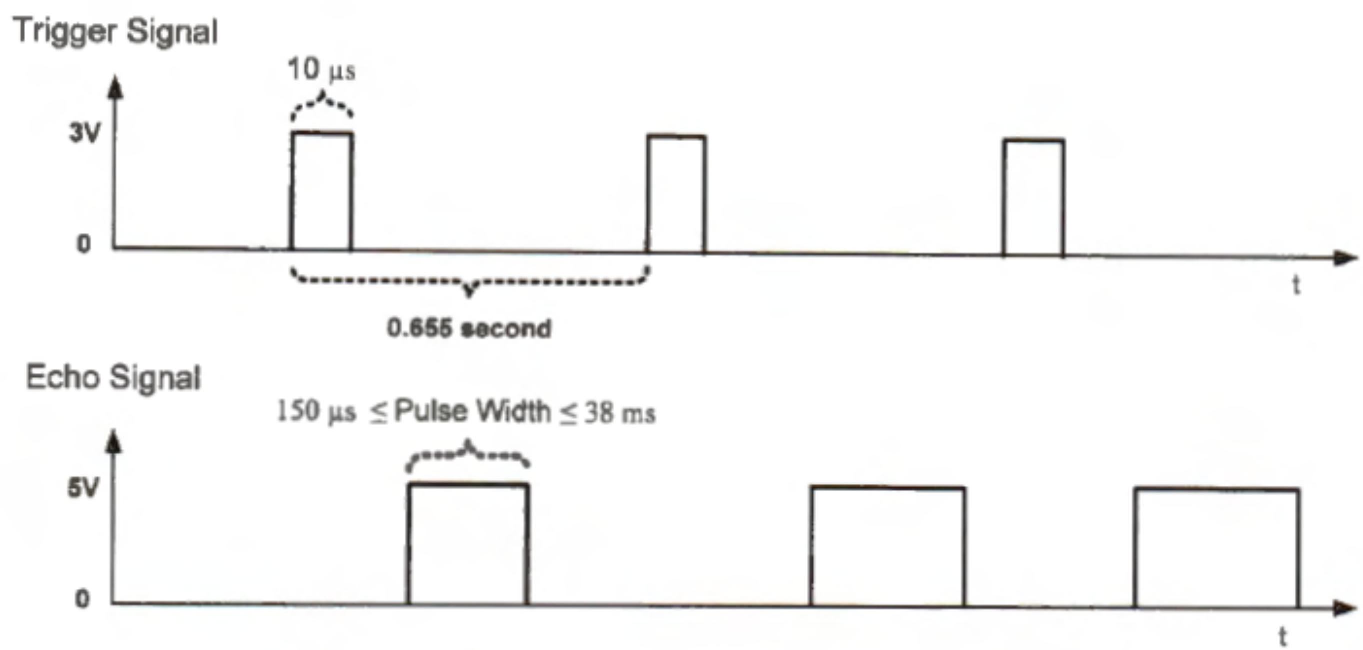
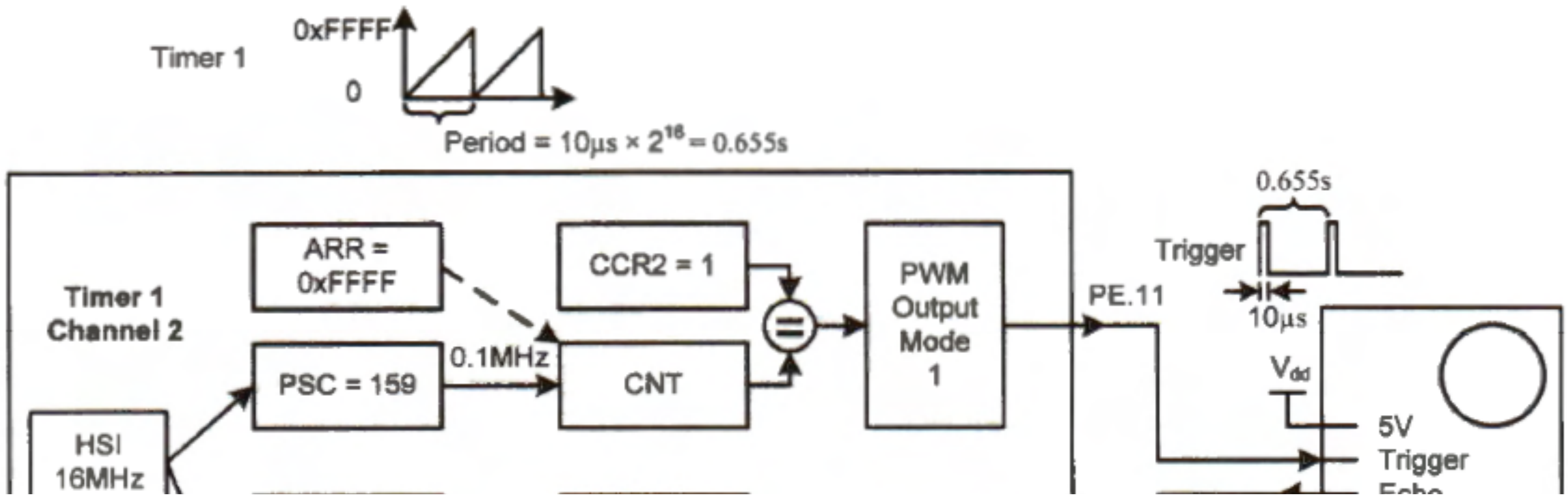


Figure 15-29. Trigger and echo signals

Ultrasonic Distance Sensor



$$Timer\ 1\ Counter\ Clock = \frac{Timer\ 1\ Input\ Clock}{1 + Prescaler} = \frac{16\ MHz}{1 + 159} = 0.1\ MHz$$

$$PWM\ Period = (1 + ARR) \times Counter\ Clock\ Period = (1 + \ 0xFFFF)\frac{1}{0.1\ MHz} = 0.655\ s$$

$$PWM\ pulse\ width = CCR \times Counter\ Clock\ Period = 1 \times \frac{1}{0.1\ MHz} = \ 10\ \mu s$$

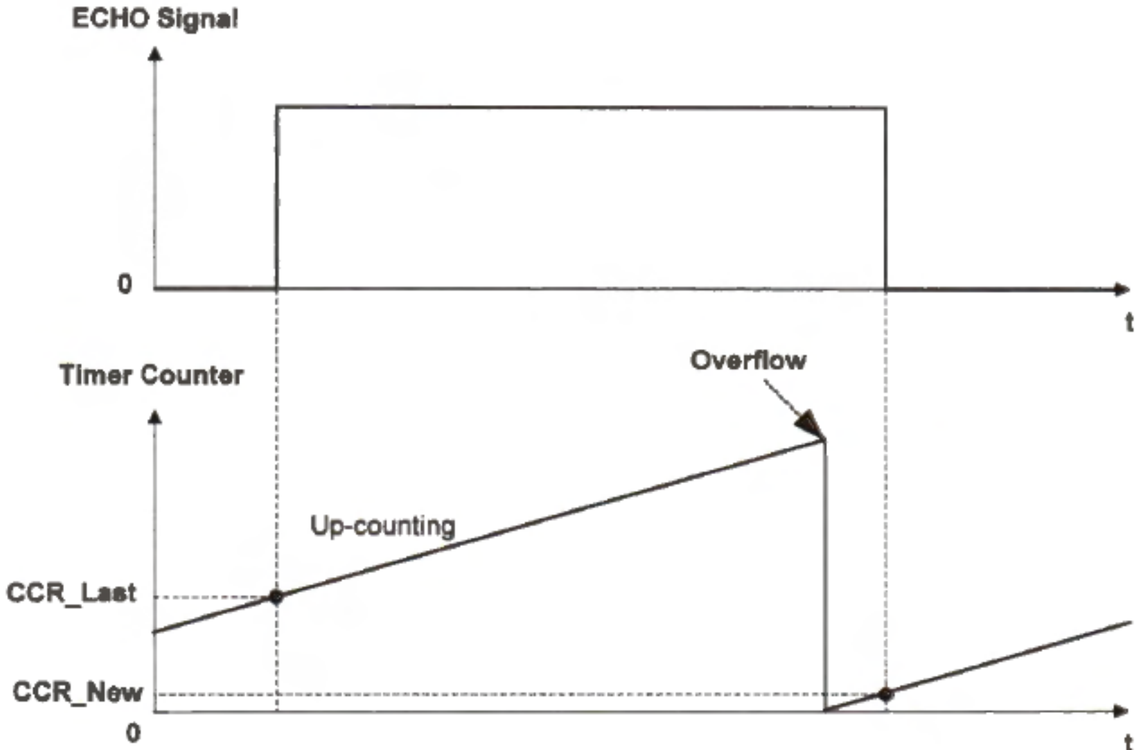


Figure 15-31. Overflow occurs between two capture events

Thus, we need a variable (named *overflow* in the following code) that counts the number of overflows within one pulse. The time span can be calculated as follows:

$$Time\ Span\ (\mu s) = (CCR_{New} - CCR_{Last}) + 65536\ \times\ Overflows$$

- END OF CLASS